



Award Description

Frost & Sullivan's Technology Innovation Award is bestowed upon a company (or individual) that has carried out new research, which has resulted in innovation(s) that have or are expected to bring significant contributions to the industry in terms of adoption, change, and competitive posture. This award recognizes the quality and depth of a company's research and development program as well as the vision and risk-taking that enabled it to undertake such an endeavor.

Research Methodology

To choose the award recipient, Frost & Sullivan's analyst team tracks innovation in key hi-tech markets. The selection process includes primary participant interviews and extensive primary and secondary research via the bottom-up approach. The analyst team shortlists candidates on the basis of a set of qualitative and quantitative measurements. The analysts also consider the pace of research and technology innovation, and the significance or potential relevance of the innovation to the overall industry. The ultimate award recipient is chosen after a thorough evaluation of this research.

Measurement Criteria

In addition to the methodology described above, there are specific criteria used to determine the final rankings. The recipient of this award has excelled based on one or more of the following criteria:

- Significance of the innovation(s) in the industry, and across industries (if applicable)
- Potential of the products of innovation(s) to become industry standard(s)
- Competitive advantage of innovation vis-à-vis other related innovations
- Impact (or potential impact) of innovation(s) on company or industry mind share and/or company bottom line
- Breadth of intellectual property related to the innovation(s), that is, patents, scientific publications, and papers in peer-reviewed journals.

2007 North American Frost & Sullivan Award for Technology Innovation

Award Recipient: Grandis Inc.

The 2007 Frost & Sullivan North American Technology Innovation Award in the field of non-volatile memory goes to Grandis Inc. of California for its development of spin transfer torque random access memory (STT-RAM). The spin transfer torque mechanism performs write operations using spin polarized current rather than magnetic fields. This switching mechanism does not require high current for writing and also improves the scalability of MRAM below the 65 nm process node. In STT-RAM, the current directly flows through every bit, which eliminates the 'false writing' problems of conventional MRAM switching mechanisms.

The switching mechanism of conventional magnetoresistive RAM (MRAM) devices is based on magnetic fields. High currents of several milliamps are required for

performing write operations in such conventional MRAM devices. Another major issue associated with conventional MRAM devices is scalability: as cell size shrinks, the writing current increases. Thus, conventional MRAM devices cannot scale beyond the 65 nm process node.

Established in the year 2002 and headquartered at Milpitas, California, Grandis Inc. develops and licenses innovative nonvolatile memory solutions, derived from its cutting-edge research in spintronics. Its proprietary STT-RAM memory technology with low writing current was invented to overcome the issues of the field-switched MRAM devices and hence it is considered to be the second generation MRAM device.

Dynamic random access memory (DRAM), static random access memory (SRAM), and flash memories are the major categories of volatile and nonvolatile memories. The applications of these memories are based on their characteristics. For example, SRAM devices have the highest operating speeds; hence they are used as embedded memory caches adjacent to the processor cores in computers. The high density of DRAM is utilized as system memory to speed data access and processing in computers, as well as in gaming and multimedia applications. Flash memories are used for storing the operating instructions and data in cell phones, personal digital assistants (PDAs), telecommunication, wireless networks, automotive and other consumer electronic applications due to their nonvolatile data storage capability. But there are a lot of issues with these memories, beyond the 45 nm process node. Scalability and poor reliability with SRAM and DRAM devices and scalability, high programming voltages, slow write and erase speeds, and limited endurance with flash memories are considered to be the major drawbacks of this node. Hence, there is an outlook for alternate technologies or improvements in existing technologies.

MRAM, ferroelectric RAM (FRAM/FeRAM), and phase change memory (PRAM/PCRAM) are considered to be the emerging and alternate technologies to conventional memories. These memories are not mass-produced. FRAM devices have low density, poor scalability (not scalable beyond 90 nm) and limited endurance. PRAM also has limited endurance as well as lower speed than MRAM. And MRAM devices draw high currents for performing writing operations.

The conventional MRAM device performs writing/switching operation based on the magnetic field, which is considered to be the first generation MRAM device. In this device, a magnetic tunnel junction (MTJ) element is used to store the data. These field-switched MRAM devices operate at high speeds but require high writing currents in the range of milliamperes. The currents that flow through the bit and word write lines, thereby generating the magnetic field that switches the MTJ elements, increase as the cell size shrinks. Hence, the field-switched MRAM device has poor scalability to future process nodes (beyond the 65 nm node).

Research has led to the evolution of an alternate switching mechanism for MRAM beyond the 65 nm process node. Grandis Inc. has developed a second-generation MRAM technology using the spin transfer switching scheme called STT-RAM. Here,

the switching states are achieved based on the electronic spin (spintronics) and the bit states are assigned based on the current flowing through the MTJ cell. The current passing through the MTJ cell is first polarized and aligned in the direction of the spinning electrons. The resultant spin-polarized current changes the direction of magnetic orientation of the storage layer in the MTJ cell, thus enabling two different digital states (high and low resistance states). This method requires low current for writing operation and also shows excellent scalability characteristics below the 65 nm process node: as the cell size shrinks, the current requirement also goes down. At the 90 nm process node, STT-RAM requires a switching current of approximately 100 microamperes and this would further reduce at the 45 nm node. Low switching current results in high density and low cost STT-RAM devices. In addition, as the writing current flows directly through every bit in an STT-RAM device, it does not have 'false write' problems. Thus, STT-RAM overcomes the drawbacks of field-switched MRAM.

The combination of high speed and scalability beyond the 65 nm process node makes STT-RAM attractive for embedded applications. It operates at ultra high speeds with modifications in the MTJ structure. The switching speed goes down to ten nanoseconds and less with these modifications. When integrated with microprocessors, microcontrollers or any system-on-chip device, it can operate at low voltages (1.2 V).

The superior performance characteristics of STT-RAM will find new application markets in the near future. Grandis has already developed test chips and it is collaborating with semiconductor manufacturers to commercialize STT-RAM-based products. Its high speed and low power consumption compared to embedded flash memories and embedded SRAM make it more suitable for automotive applications. For consumer electronics applications, it can be treated as a universal memory. Mobile phones consist of both volatile and nonvolatile memories, but a single STT-RAM can replace these memories and offer the advantages of both. It can even be used in CPU caches due its high speed.

Grandis partnered with Renesas Technology (Tokyo) in 2005 to develop STT-based MRAM at 65 nm process node and it plans to incorporate this technology in Renesas microcontrollers and system on chip (SoC) products. Singulus Technologies and Grandis are jointly developing the TIMIRAS thin film deposition system for STT-RAM technology. Grandis also works with various universities on STT-RAM technology.

To date, Grandis has received research grants totaling approximately \$700,000 from the National Science Foundation (NSF) to develop and commercialize ultra fast, nonvolatile MRAM device based on the spin transfer mechanism. Grandis initially received a Phase I grant from NSF under the Small Business Innovation Research (SBIR) program to initiate STT-RAM research and development process. A more recent SBIR Phase II grant focuses on the development and commercialization process of STT-RAM-based products. Grandis will leverage its expertise for exploring STT-RAM characteristics in single and dual MTJ elements to build prototype memory

arrays based on the research. Since 2002, Grandis has also received venture capitalist funding of \$15 million to develop and commercialize STT-RAM technology.

Grandis Inc. has a wide range of patents in STT-RAM technology, which range from the fundamentals of STT-RAM to the implementation methods. It is the result of extensive research carried out in the field of spintronics. It has 30 patents issued by the US patent office and in total has 80 granted and pending patents worldwide. It licenses the technology, comprising all the processes starting from designing to testing, to fab/fabless semiconductor manufactures and integrated device manufacturers (IDM's). The STT-RAM technology can be used in standalone as well as in embedded memory devices.

Grandis focuses on embedded devices using STT-RAM technology at 65 nm process node and, prototype chips of 1 megabit (Mb) density have already been fabricated in this line. The products are expected for commercialization by the end of 2008 or beginning of 2009. Standalone STT-RAM devices at 45 nm process node are expected to enter the memory market by 2010 or 2011.

The second generation STT-based MRAM is a promising technology compared to field-switched MRAM, PRAM, and FRAM devices. This technology holds well when conventional MRAM finds problems with 65 nm process node. It is considered to be a disruptive technology for SRAM, DRAM, and flash memory devices. It combines the high speed of SRAM with the high density of DRAM and flash. Hence, it can be envisioned as a universal memory replacing conventional technologies. 1 Mb prototype chips are developed and Grandis has received funding from NSF for commercialization. Grandis targets embedded memory markets in its first state. It leverages its expertise for improving the performance of STT-RAM using multiple MTJ elements. Frost & Sullivan therefore bestows the 2007 North American Technology Innovation Award on Grandis Inc. for its incredible research on spintronics-based devices and for developing STT-RAM devices based on spintronics.

About Best Practices

Frost & Sullivan Best Practices Awards recognize companies in a variety of regional and global markets for demonstrating outstanding achievement and superior performance in areas such as leadership, technological innovation, customer service, and strategic product development. Industry analysts compare market participants and measure performance through in-depth interviews, analysis, and extensive secondary research in order to identify best practices in the industry.

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